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AMRL-TDR-62-121

ONE-MINUTE TOLERANCE IN MAN TO VERTICAL SINUSOIDAL VIBRATION IN THE SITTING POSITION

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TECHNICAL DOCUMENTARY REPORT No. AMRL-TDR-62-121

OCTOBER 1962

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6570th AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Project No. 7231, Task No. 723101

FOREWORD

This work was done in support of Project No. 7231, "Biomechanics of Aerospace Operations," Task No. 723101, "Effects of Vibration and Impact." The Vibration and Impact Section, Bioacoustics Branch, Biomedical Laboratory, 6570th Aerospace Medical Research Laboratories, performed this research between December 1960 and December 1961. The authors wish to acknowledge the valuable assistance of Mr. William Cindrick in the completion of this project.

ABSTRACT

One-minute subjective tolerance in man to sinusoidal vertical vibration was determined in the sitting position. In comparing the data to previously published information, we noted that, although the new levels were higher, the contour of the curve remained unchanged. The reasons for this difference, as well as specific subjective complaints leading to tolerance, are presented and discussed.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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INTRODUCTION

Subjective tolerance in man to whole-body vibration was reported in a recent communication from this laboratory (ref. 1). Subjective tolerance was defined as that point at which the subject felt he could no longer endure the vibration exposure due to specific pains arising during the vibration period. The previous report presented subjective tolerance for short-time, 1-minute, and 3-minute exposures. Although the short-time tolerance was determined for each subject, most of the 1-minute and all of the 3-minute values were predicted from the short-time tolerance points.

For the measurement of any physiological function, short-time tolerance studies would not be applicable. We thought that a more precise evaluation of the 1-minute tolerance would be in order at this time since any physiological changes that might be detected during a short-time tolerance run might be due to the changing amplitude rather than the vibration level per se.

Moreover, preliminary observations of the subjects during vibration revealed two factors not previously reported. One of the most important considerations during vibration is the problem of respiration. In all subjects observed, respiration became markedly erratic during the vibration exposure with a propensity to aerophagia. A low tolerance level was an invariable consequence. When the subjects were indoctrinated to concentrate on a regular breathing pattern, tolerance levels were enhanced and aerophagia was minimized. Due to the marked difference in our preliminary studies from those of Magid, Coermann, and Ziegenruecker (ref. 1), we decided that 1-minute tolerance levels should be re-evaluated.

METHODS

Twenty-two male subjects, ranging in age from 22 to 34 years old, in weight from 140 to 230 pounds, and in height from $65\frac{1}{2}$ to $73\frac{1}{2}$ inches, were used in these studies. The subjects had been on the Vibration Hazardous Duty Panel from at least 2 months to 2 years and had been well indoctrinated in the problem of respiration.

To minimize the number of variables, each man voided prior to each shake and had defecated within 24 hours prior to vibration, usually just prior to the test run. In most cases, they had a light liquid breakfast the morning of the shake; however, no difference in tolerance levels was noted when this was not followed. Once a subject had reached a tolerance point at any given frequency, he was not repeated on that same day since subsequent tolerance levels were noted to be reached more rapidly at any subsequent frequency within this narrow range.

A Western Gear mechanical shake-table, capable of increasing amplitude at a constant rate of 0.75 millimeter double amplitude per second, was employed. During the period of vibration, the frequency was preset and the amplitude was approached from a zero baseline until the predetermined acceleration level was obtained. This took from 110 seconds at the lowest frequency to 18 seconds at the highest frequency. Timing of the run did not begin until the predetermined G-level was reached. The tolerance values were accepted if the subject shook from 50 to 70 seconds. Due to the time limit imposed in these experiments, an average of 2 to 3 determinations was required for each tolerance point.

Because of the problem of breathing, all subjects breathed through a mouthpiece communicating with air. The mouthpiece served as an excellent reminder to the subject to breathe regularly. Resistance of the system to airflow was minimal and the effect on the tolerance levels was negligible. A lapbelt shoulder harness was used as the restraint system as shown in figures 1 and 2. The footrests were attached to the vibration table and set so the subject could brace himself in the chair. This was particularly important at the higher amplitude encountered during the lower frequencies. A unit was also attached to the armrest whereby the subject could stop the machine whenever he felt his subjective tolerance had been attained.

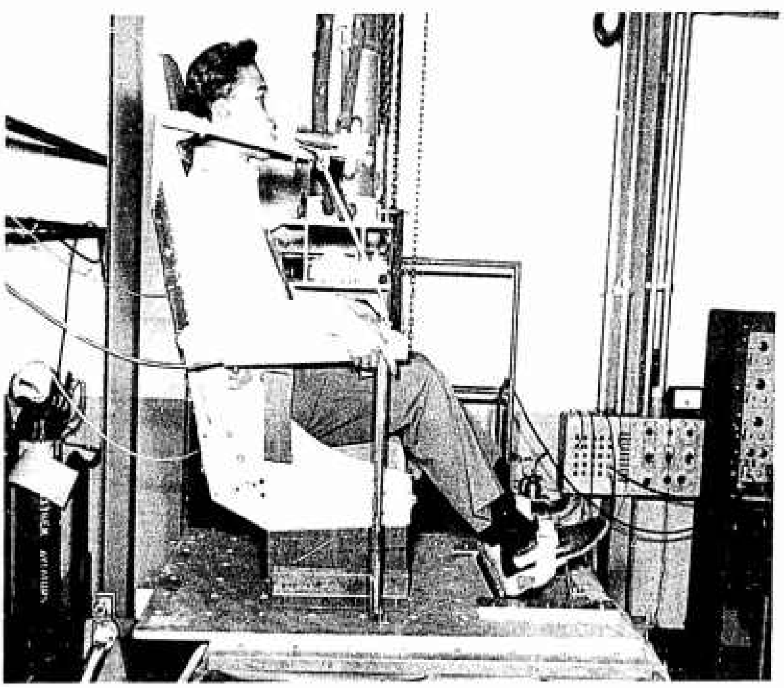

Figure 1. Illustrates Position of Subject and Restraint System (Side View)

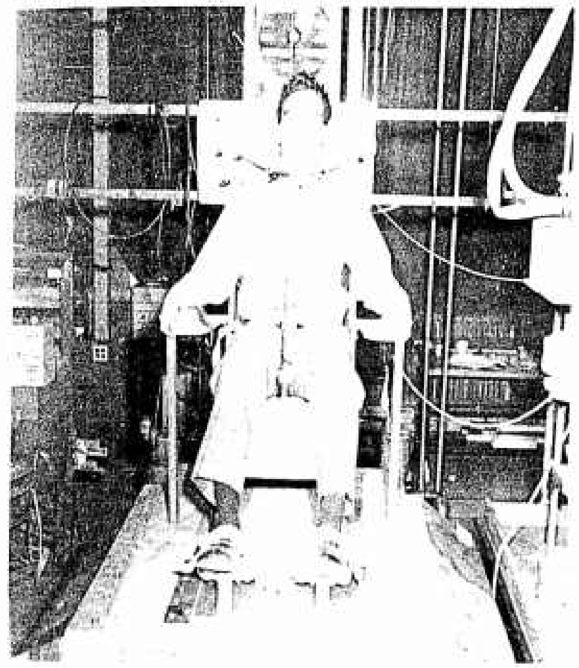

Figure 2. Illustrates Position of Subject and Restraint System (Front View)

RESULTS

The results of this study are shown in table I and figure 3. It should be stressed that figure 3 is not an attempt to draw a tolerance curve but rather to show the tolerance contour. The values presented in table I were reproducible in the same individual from day to day with rare exception.

TABLE I

ONE-MINUTE TOLERANCE TO VERTICAL SINUSOIDAL VIBRATION IN THE SITTING POSITION

(Expressed in G-units)

	Frequencies (cps)						
	4	5	6	7	8	9	10
	>2.6*	2.6	1.7	1.6	2.0	2.0	2.5
	>2.4*	1.9	1.8	1.4	2.2	2.0	2.7
	>2.6*	2.2	1.6	1.4	2.2	2.1	2.5
	>2.5*	1.9	1.9	1.6	2.3	2.0	2.9
	>2.6*	2.4	1.7	1.9	2.0	2.1	2.7
	>2.6*	2.1	1.6	1.5	2.3	1.8	2.8
	>2.6*	2.2	1.5			2.3	2.6
	1.8		1.5				
Average		2.2	1.7	1.6	2.2	2.0	2.7
S.D.		±0.3	±0.2	±0.2	±0.1	±0.2	±0.2

* No body tolerance - see text.

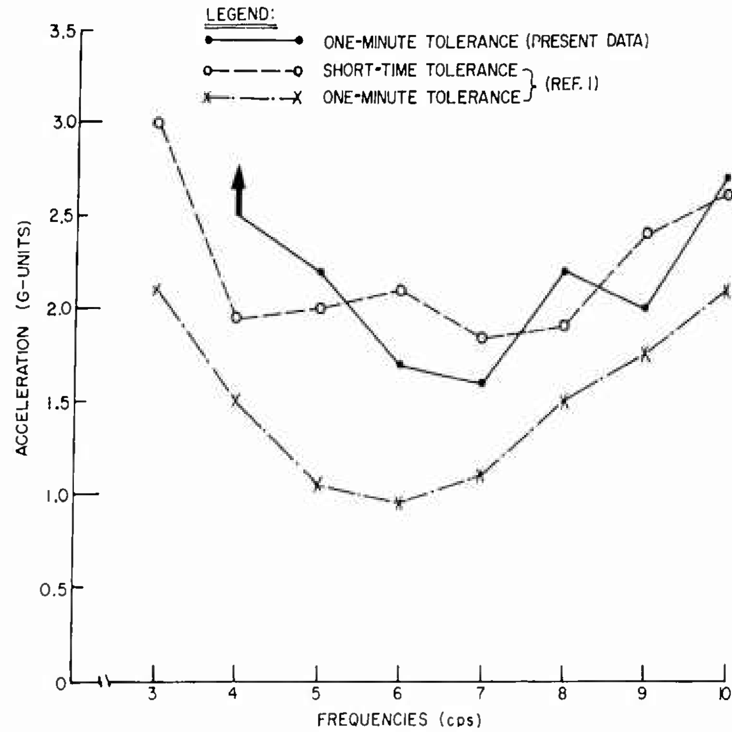

Figure 3. Tolerance to Vertical Vibration in the Sitting Position

The 4-cps group is unique in that the tolerance was never achieved with the exception of the one subject who had a subjective tolerance of 1.8 G's. Fatigue was a constant complaint although an abortion did occur occasionally due to headache. This was not a constant factor in any individual from one exposure to the next at this particular frequency, with the one exception noted. It should also be stressed that this subject has an emotionally unstable personality and all tolerance levels obtained by him were accompanied with great emotional display. Headache was an invariable accompaniment at the 4-cps level in this individual, the type of head pain being quite variegated from one exposure to the next.

In comparing our results with those of Magid, Coermann, and Ziegenruecker (ref. 1), we see in figure 3 that not only were our 1-minute tolerance levels in marked contrast to those reported previously, but also they exceeded those of the short-time levels with the exceptions of 6, 7, and 9 cps. Table II shows the symptoms responsible for tolerance under these conditions. At 4 cps, fatigue was an invariable accompaniment but not a tolerance factor per se. Inspiratory dyspnea played a prominent role in all frequencies ranging from 5 to 10 cps, but was usually secondary or accompanied by either subcostal or substernal pressure, or, at times, by both. Precordial symptoms were extremely unusual in this study. Epigastric pressure was a very common complaint between 6 and 8 cps and accompanied inspiratory dyspnea. At 9 and 10 cps, periumbilical pressure played a more prominent role.

We attempted to correlate body size and physical condition to tolerance factors, but could find no such correlation in our studies. In addition, the length of time the member had been on the panel or the number of times he had been subjected to vibration over a period of months to years appeared to have no effect on his tolerance levels. Although tolerance levels during the first several exposures to vibration for a subject were usually lower, once the subject learned to adapt himself to the vibration problems such as respiration and apprehension, his tolerance level was almost reproducible from one run to the next.

TABLE II

SYMPTOMS CAUSING TOLERANCE

	FREQUENCIES (cps)						
	4	5	6	7	8	9	10
A. GENERAL							
I. Confusion						2	
II. Fatigue	2222		2		2	2	
B. HEAD							
I. Headache							
a. Frontal	2		1				
b. Occipital				1			
c. Parietotemporal	1	11				2	
C. CHEST							
I. Respiration							
a. Inspiratory dyspnea		11	11	111	111	111	1111
b. Expiratory dyspnea							1
c. Subcostal pressure		1	211		12	1	1
d. Substernal pressure	2	111	11	211	111	?	11
e. Precordial pressure				1	2		
D. ABDOMEN							
I. Epigastric pressure		1	111	11	11		
II Periumbilical			1	1	1	2121	111
III. Right lower quadrant						1	
IV. Left lower quadrant		1		1			

1 - Tolerance factor
2 - Other symptoms noted, but not necessarily related to tolerance

DISCUSSION

The marked disparity between our data and that of Magid, Coermann, and Ziegenruecker (ref. 1) is probably due to the difference in breathing. Several of the subjects used in the previous studies were also used in this study with tolerance levels much higher than those previously noted. This is not a matter of accommodation since their tolerance levels are in good accord with those of more recent members of the panel. Moreover, as previously noted, unless the subject had been indoctrinated to the problem of respiration, his tolerance levels were much lower than runs after indoctrination. As will be recalled, aerophagia was the inevitable consequence of erratic respiration. Although this was not completely eliminated, it was certainly minimized subsequent to restoration of a regular breathing pattern. The severe abdominal and chest pains which the subjects noticed could well be related to increased intraluminal pressure due to both increased volume and increased compression of gas during the vibration exposure. It is noteworthy that on several occasions eructation could completely eliminate the chest symptoms. On several occasions this was also noted following the passage of flatus.

The shape of the short-time curve is quite similar to that previously reported (ref. 1) showing a rapid rise after 9 cps and below 5 cps with a minimum at 6 and 7 cps. Although mechanical injury of the organs has been incriminated as the major cause for limiting tolerance, physiological parameters have not been measured and cannot be excluded at this time. We feel that the 1-minute tolerance value gives us another tool for measuring physiological functions during any vibration level per se without fear of being confounded by the rate of change of the vibration level.

REFERENCE

1. Magid, E.B., R.R. Coermann, and G.H. Ziegenruecker, "Human Tolerance to Whole-Body Sinusoidal Vibration," J. Aerospace Med., Vol 31, pp 915-924, 1960.

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1. Vibration tolerance
2. Subjective tolerance
3. Vertical vibration
4. Sinusoidal vibration
5. Shake-Table

I. AFSC Project 7231, Task 723101
II. Biomedical Laboratory
III. Mandel, M. J., Captain, USAF, MC; Lowry, R. D.
IV. In ASTIA collection
V. Aval fr OTS: $0.50

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